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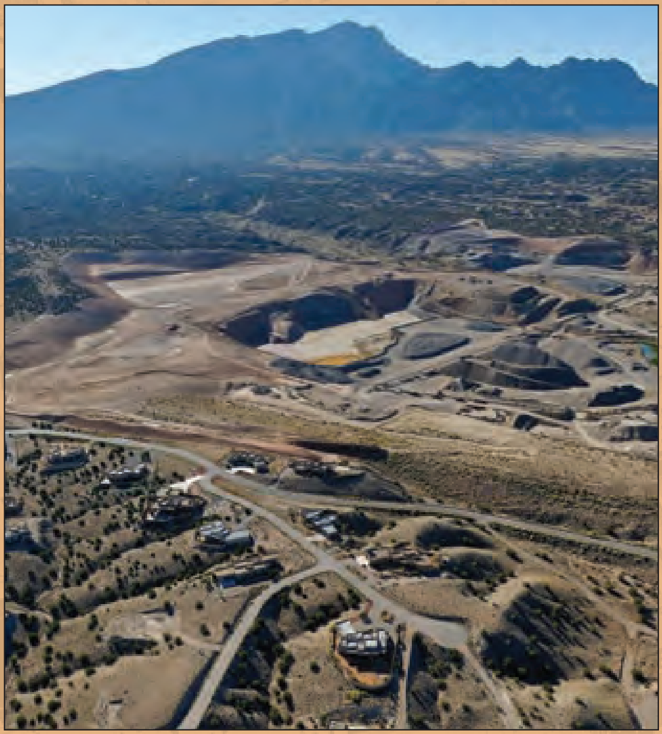

Oil and Natural Gas Potential of the Albuquerque Basin

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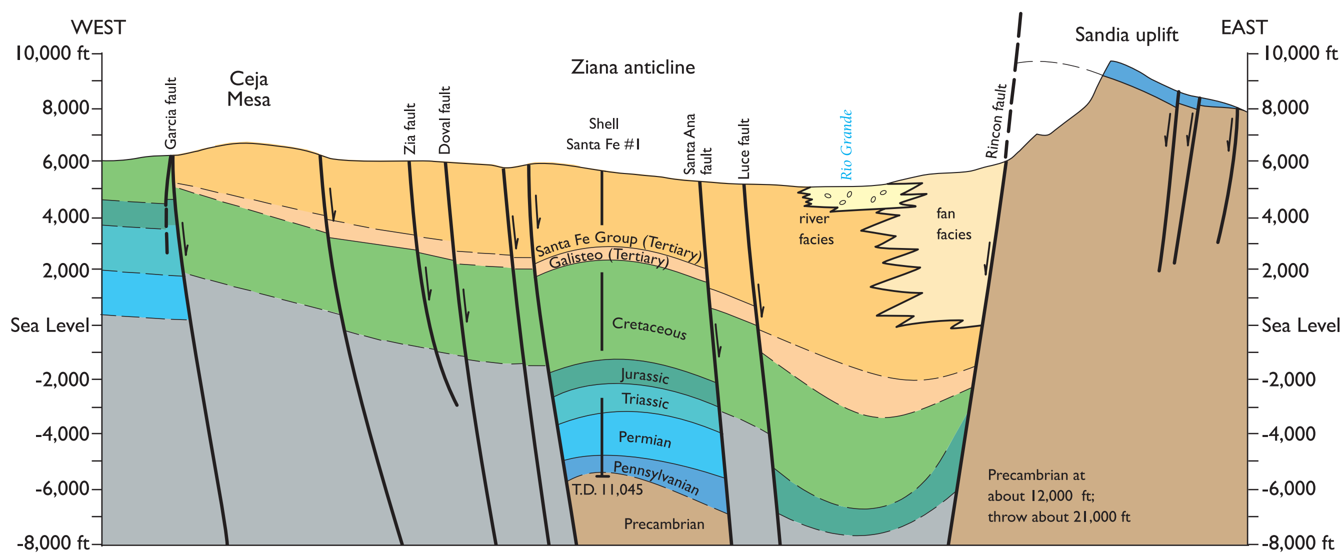
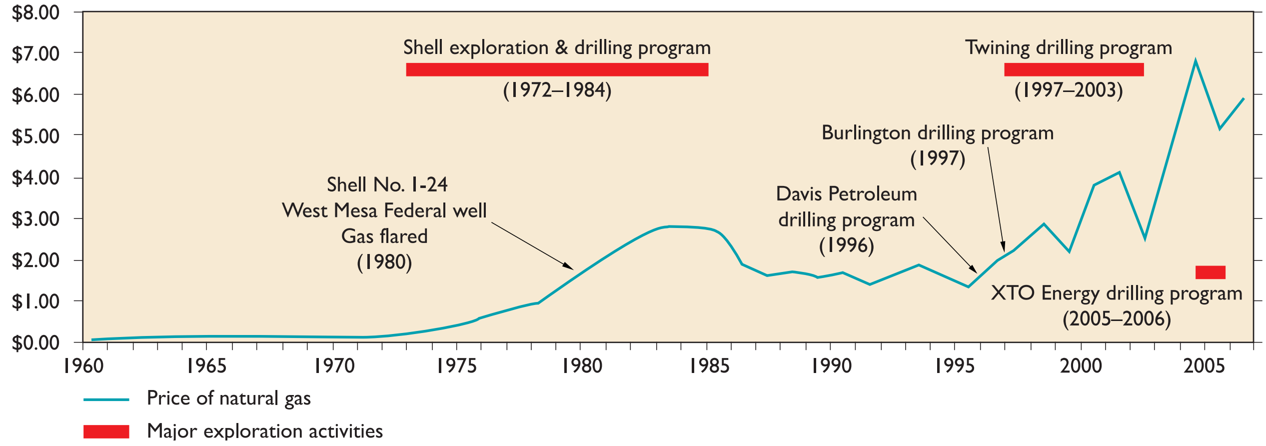
The Albuquerque Basin is one of several north-south aligned basins in New Mexico that form the Rio Grande rift. The Albuquerque Basin was formed by extensive faulting during the Tertiary Period, and its thick fill of Tertiary-age sands, gravels and clays (more than 4 miles thick in places) reflect its history of Tertiary faulting, subsidence, and sedimentary infilling. Beneath the Tertiary sediments lies a thick section of Cretaceous strata (as much as 5,000 feet thick) that is broadly similar in character to Cretaceous strata that are prolifically productive of natural gas in the San Juan Basin of northwestern New Mexico. Beneath the Cretaceous are 2,500 feet of Jurassic and Triassic strata, 2,000 feet of Permian sedimentary rocks, and almost 3,000 feet of Pennsylvanian-age sandstones, shales, and limestones. Cretaceous sedimentary rocks have been the objects of considerable oil and natural gas exploration since the 1950s. Some recently acquired data indicate that the deeper Paleozoic (Permian) section may have some intriguing natural gas possibilities as well.

In order for oil and/or natural gas to be present in a basin, four geologic elements are required: source rocks, reservoir rocks, seals, and traps. For an oil or gas field to form, all four of these geologic elements need to be present, and they need to be present in a geologically suitable arrangement. Oil and natural gas are generated from organic matter in a source rock after it is heated by deep burial in the earth's crust. The organic matter in the source rock is the altered remains of organisms that died at the time of deposition of the sedimentary rock and were incorporated into the rock-forming sediment and preserved through its burial. After the source rock is buried and heated to high temperatures for a sufficient period of time (millions or hundreds of millions of years, depending on the maximum temperatures attained), oil and/or natural gas are generated from the organic matter and expelled under pressure into adjacent reservoir rocks. In essence the elevated temperatures, if persistent over a long period of time, cause the organic matter to be "cooked."

Reservoir rocks are porous and permeable, that is, they contain a system of interconnected microscopic holes (pores) that allow oil, gas, and water to move through the rock. The pore system in reservoir rocks is filled with water (usually fresh at shallow depths and saline at greater depths) before oil and gas are generated in the source rocks. When oil or gas is expelled from the source rock into the reservoir, it



West-to-east cross section through the Albuquerque Basin showing distribution of strata and major structures. Cretaceous strata (shown in green) are the major targets for natural gas exploration in the basin. After Kelley 1977.



Average annual price of New Mexico natural gas (in dollars per thousand cubic feet) and major exploration activities in the Albuquerque Basin. Based on data from the New Mexico Taxation and Revenue Department, the New Mexico Energy, Mineral and Natural Resources Department, and the New Mexico Bureau of Geology and Mineral Resources.

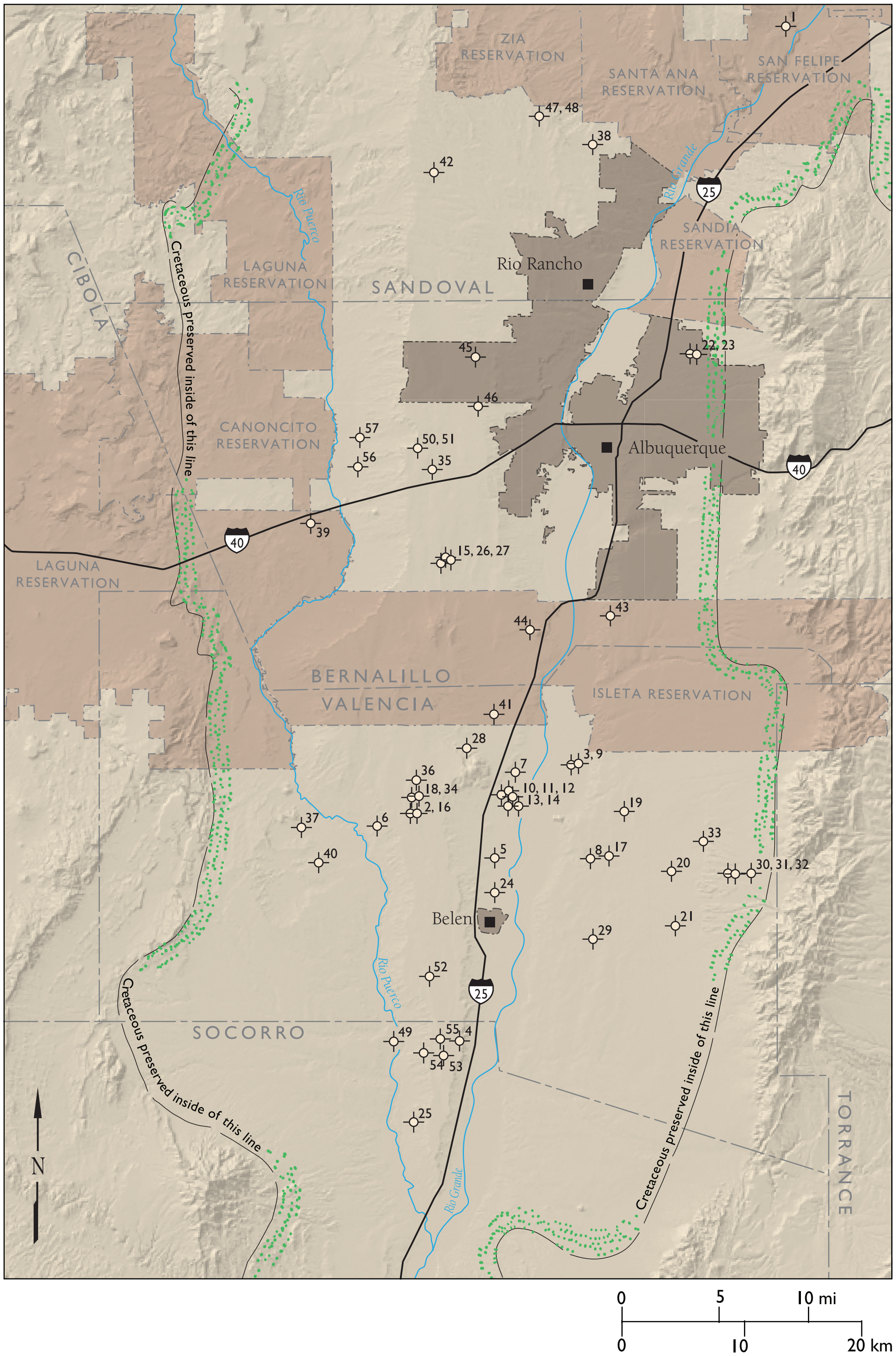
moves upward through the water-saturated pore system, because both oil and gas are less dense than water. Both the water and the oil and gas are contained in the reservoir by seals: nonporous, impermeable rocks that block the movement of fluids in the subsurface. When the oil or gas has moved upward to a place where further upward movement is blocked, a trap is formed, which results in an oil or gas field.

In the Albuquerque Basin, organic-rich source rocks are found in black, organic-rich shales of Cretaceous age. In the shallower parts of the basin, analyses of drill cuttings reveal that these rocks have not been heated to a sufficiently high temperature for a sufficient length of time to have generated maximum amounts of oil and gas—essentially they are undercooked in these areas. In deeper parts of the basin, the organic-rich Cretaceous shales have been cooked sufficiently to have yielded the maximum amount of oil and gas possible given their organic content—in geologic parlance, they are thermally mature. In many of the deeper areas, temperatures have been sufficiently high so that oil has been naturally refined into natural gas and gas liquids (including propane). The types of organic matter present in the Cretaceous shales indicate that they have generated mostly natural gas with secondary amounts of oil in places where they are mature. Therefore, the primary potential in the Albuquerque Basin is for natural gas. Reservoirs are Cretaceous sandstones that are interlayered with the shales. The shales form the seals as well as the source rocks. Exploration focuses on finding geographic areas that may be underlain by traps. The primary potential is for gas and associated natural gas liquids (including propane) or light oils in the deeper (greater than 15,000 feet) parts of the basin. Where shallower areas with immature source rocks are connected by migration pathways with deep areas of mature source rocks, the shallower areas are favorable as well. To date, most verifiable major shows of gas and oil encountered by exploratory wells have been in the deeper parts of the basin.

DRILLING AND EXPLORATION HISTORY

Oil and natural gas have been the targets of exploratory drilling in the Albuquerque Basin since the Tejon Oil and Development Corporation No. 1 well was drilled to a total depth of 1,850 feet between July 1912 and July 1914. By 1952 a total of 36 wells had been drilled, mostly to shallow depths less than 5,000 feet. These early wells were drilled primarily into Tertiary-age strata. Their locations and drill depths were based on concepts that lacked a modern understanding of the geology and geometry of the basin as well as a modern understanding of how oil and natural gas form and accumulate. Noncommercial "shows" of oil and gas were reported from many of the wells. However, because the nature of the shows was often not described, the authenticity of some of them may be in question.

The first well to penetrate and evaluate a significant thickness of Cretaceous strata was the Humble No. 1 Santa Fe Pacific well, drilled in 1953. Until this well was drilled, the presence of a deep rift basin filled with Tertiary-age sands, gravels, and clays as much as 22,000 feet (4 miles) thick was unrecognized. This well marked the beginning of modern exploration in the basin and provided the first geologic information on the depth, structure, and origin of the basin. A



Exploratory oil and gas wells that have been drilled in the Albuquerque Basin. Also shown is the limit of Cretaceous strata that defines the basin boundaries for exploration purposes. Well numbers refer to those in the table on the following pages.

nineteen-year hiatus ensued before the next exploratory well was drilled in the Albuquerque Basin.

During the 1970s and early 1980s the first sustained oil and natural gas exploration effort began in the basin. During this period Shell Oil Company conducted extensive seismic reflection surveys and drilled seven unsuccessful deep (and expensive) exploratory wells, several of which encountered noncommercial volumes or "shows" of oil and natural gas. As expenses for the exploration program mounted without a return on investment, Shell partnered with other companies to drill an additional two wells. Natural gas was reportedly flowed and flared at the Shell No. 1 West Mesa Federal well, but large expenses associated with drilling this deep (19,375 feet) well, combined with the low price of natural gas and apparently limited flow rates, contributed to the noncommercial nature of the reservoir encountered by the well. The UTEX Oil No. 1 Westland Development was drilled by UTEX Oil Company in collaboration with Shell and represented the last unsuccessful gasp of the Shell effort. Still, the wells drilled by Shell and its partners provided invaluable geologic information that has helped geologists develop an understanding of basin geology and has provided the foundation for all subsequent exploratory efforts.

The basin saw no further exploratory drilling until the post-Shell exploration phase began in 1995. In that year Davis Petroleum, in conjunction with Vastar Resources, drilled two exploratory wells. The first well was drilled near the northern end of the Albuquerque Basin. This well drilled the entire Cretaceous section but encountered only minor shows and was subsequently abandoned and converted to a water supply well. The second well was drilled at the southern end of the Albuquerque Basin and was abandoned when they reached volcanic rocks of Tertiary age. Similar to early wells in the basin, drilling depth was inadequate to penetrate Cretaceous strata, the primary exploration targets in the basin.

Burlington Resources followed by drilling two wells in the West Mesa area in 1997 outside of Albuquerque. These wells were located in the relatively shallow western part of the basin. Again, no production of either oil or natural gas was established. The Burlington No. 1Y Westland Development well was re-entered by Tecton Resources in 2007; a test of the Jurassic-age Morrison Formation near the bottom of the hole apparently resulted in recovery of water. Plans were announced to move uphole and test the Cretaceous-age Dakota Sandstone, but work of this nature had not taken place when this article was written. Further to the west and also on the West Mesa, XTO Energy drilled two wells during 2005 and 2006 to test the Cretaceous Menefee Formation, a known coal-bearing rock layer, for coalbed methane potential. After coring and extensive evaluation, the wells were plugged and abandoned without establishing production. Minor gas shows were recorded in at least one of the wells.

At the southern end of the basin, Twining Drilling Corporation drilled a series of wells during the late 1990s and early 2000s. Little data are available for these wells. Apparently most of the wells were drilled to an insufficient depth to penetrate Cretaceous strata, the primary modern exploration targets in the basin. None of the wells established production.

THE FUTURE OF OIL AND NATURAL GAS EXPLORATION IN THE BASIN

Rising prices for natural gas have generally been associated with increased exploration in the Albuquerque Basin. Within the last decade, average annual prices for natural gas have risen from less than $2 per thousand cubic feet to more than $5 per thousand cubic feet, with prices in 2008 exceeding $10 per thousand cubic feet on occasion. As a result, interest in exploration for natural gas and associated natural gas liquids and light oils has increased and will no doubt persist into the future. Wells drilled as part of Shell's exploration program in the 1970s and the post-Shell exploration that began in the 1990s have yielded an abundance of geologic information that previously did not exist and have provided invaluable information with which to understand the geology and petroleum potential of the basin. The refined geologic models derived from these data, as well as advanced, modern geologic concepts, will be used to identify target areas that have a maximum potential for yielding natural gas and oil and therefore lowering, but certainly not eliminating, the risk of drilling unsuccessful exploratory wells. The steep rise in natural gas prices over the past few years, plus improved exploration, drilling, and completion technology, will enhance the economics of exploring for, drilling for, developing, and producing natural gas in a basin such as Albuquerque where the target reservoirs occur at depths of 15,000 to 20,000 feet or more over large parts of the basin. Wells at these great depths will each cost several million dollars to drill, test, and complete. Higher natural gas prices can turn an uneconomic well into a commercial one. The high costs of drilling and inadequate technology were at least partially responsible for the abandonment of several of the deep

WELL NUMBER AND NAME	LOCATION (SECTION-TOWNSHIP-RANGE)	YEAR COMPLETED	TOTAL DEPTH (FEET)	REMARKS
1 Tejon Oil Development	7-14N-6E	1914	1,850	Reported oil show @ 1,000 ft.
2 Cal-New Mexico Dechares No. 1	8-6N-1E	1925	2,900	Reported oil & gas show.
3 Stone No. 1	25-7N-2E	1926	1,405	
4 Belen Oil Seipple No. 1	23-4N-1E	1926	3,545	Reported oil show.
5 Gilmore & Sheldon No. 1 Tome Grant	30-6N-2E	1926	1,180	
6 Hub Oil No. 1 HNTH	13-6N-1W	1926	3,425	
7 Stone No. 1 Horland	32-7N-2E	1927	2,144	Reported oil show.
8 Gilmore & Sheldon No. 1 Tome	30-6N-3E	1928	1,100	
9 Stone No. 2	25-7N-2E	1928	1,976	Reported oil show.
10 Harlan No. 1 Harlan Ranch	5-6N-2E	1930	4,223	Reported gas show.
11 Harlan No. 2 Harlan Ranch	5-6N-2E	1930	4,021	
12 Harlan No. 3 Harlan Ranch	5-6N-2E	1931	6,474	Reported gas shows.
13 Harlan No. 4 Harlan Ranch	5-6N-2E	1931	3,820	Reported oil & gas shows.
14 Harlan No. 5 Harlan Ranch	5-6N-2E	1931	4,007	Reported gas shows.
15 Norins No. 1 Pajarito Grant	22-9N-1E	1931	5,104	Reported oil & gas shows.
16 Western Natural Resources No. 1	5-6N-1E	1932	1,725	
17 Mills No. 1 Tome	29-6N-3E	1933	507	
18 Big Three No. 1 Dalies	5-6N-1E	1937	6,113	Reported oil shows.
19 Mills No. 2 Tome	9-6N-3E	1932	446	
20 Ringle Development Co. No. 1 Fee	36-6N-3E	1935	1,115	
21 Ringle Development Co. No. 1 Fuqua	13-5N-3E	1935	100	
22 Norins No. 1 North Albuquerque Acres	19-11N-4E	1935	573	
23 Norins No. 2 North Albuquerque Acres	19-11N-4E	1935	5,024	Reported CO_2 gas show.
24 Ringle Development Co. No. 1 Ringle	6-5N-2E	1935	750	
25 Central New Mexico Oil Co. No. 1 Brown	17-3N-1E	1937	2,840	Reported oil & gas shows.
26 Norins No. 2	22-9N-1E	1928	385	
27 Norins No. 3 Pajarito	22-9N-1E	1938	2,780	Completed as water supply well.
28 Joiner Petroleum No. 1 San Clemente	23-7N-1E	1939	5,606	Reported gas show.
29 Grober No. 1 Fuqua	19-5N-3E	1940	3,978	
30 Ringle No. 1 Tome	34-6N-4E	1947	823	Reported gas shows.
31 Ringle No. 2 Tome	35-6N-4E	1947	890	Reported oil show.
32 Ringle No. 3 Tome	34-6N-4E	1947	597	
33 S.M. Castleberry No. 1 Tome	20-6N-4E	1947	500	

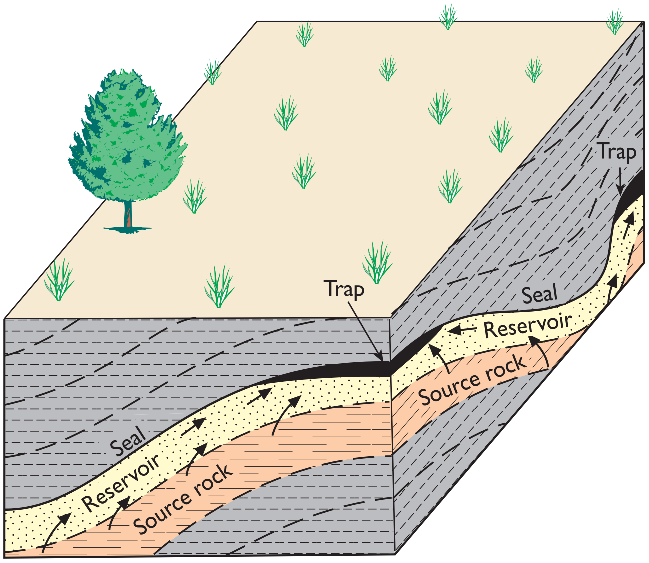
WELL NUMBER AND NAME	LOCATION (SECTION-TOWNSHIP-RANGE)	YEAR COMPLETED	TOTAL DEPTH (FEET)	REMARKS
34 Von Glahn No. 1 Dalies	5-6N-1E	1949	6,096	Reported oil & gas shows.
35 Carpenter No. 1 Atrisco	28-10N-1E	1948	6,652	
36 Long No. 1 Dalies	32-7N-1E	1952	6,091	Reported show oil & gas.
37 Humble Oil Co. No. 1 Santa Fe Pacific	18-6N-1W	1953	12,691	Reported gas show. Cretaceous strata from 9,930 to 12,691 ft.
38 Shell No. 1 Santa Fe Pacific	18-13N-3E	1972	11,045	Reported oil & gas shows in Cretaceous strata.
39 Shell No. 1 Laguna Wilson Trust	8-9N-1W	1972	11,115	Reported gas shows from Cretaceous strata.
40 Shell No. 2 Santa Fe Pacific	29-6N-1W	1974	14,305	Reported gas shows in Cretaceous strata.
41 Shell No. 1 Isleta	7-7N-2E	1974	16,346	Well reported to have flowed noncommercial volumes of gas from Cretaceous strata.
42 Shell No. 3 Santa Fe Pacific	28-13N-1E	1976	10,276	Reported minor gas shows in Cretaceous strata.
43 Transocean Oil Co. No. 1 Isleta	8-8N-3E	1978	10,378	Reported gas shows in Cretaceous strata.
44 Shell No. 2 Isleta	16-8N-2E	1979	21,266	Did not reach Cretaceous rocks.
45 Shell No. 1 West Mesa Federal	24-11N-1E	1980	19,375	Gas flared from Cretaceous reservoirs.
46 UTEX Oil No. 1 Westland Development	1-10N-1E	1984	16,665	T.D. in Tertiary basin fill.
47 Davis Petroleum No. 1 Tamara 3	3-13N-2E	1995	1,087	Well abandoned due to drilling problems. Replaced by No. 1Y Tamara (No. 49).
48 Davis Petroleum No. 1Y Tamara	3-13N-2E	1996	8,732	T.D. in Triassic. Minor shows reported. Converted to water supply well.
49 Davis Petroleum No. 1 Angel Eyes	19-4N-1E	1996	8,074	T.D. in Tertiary-age volcanic rocks.
50 Burlington Resources No. 1 Westland Development	21-10N-1E	1997	1,833	T.D. in Tertiary-age sediments. Well abandoned due to drilling problems. Replaced by No. 1Y Westland Development (No. 52).
51 Burlington Resources No. 1Y Westland Development (re-entered by Tecton Resources in 2007)	21-10N-1E	1997 (2007)	7,800	T.D. in Triassic. Re-entry perforated Morrison Formation (Jurassic) and recovered water.
52 Twining Drilling Corp. No. 1 NFT	33-5N-1E	1997	7,441	T.D. in Tertiary sediments. Plugged & abandoned.
53 Twining Drilling Corp. No. 3 NFT	27-4N-1E	2001	6,908	T.D. in Tertiary sediments. Perforated 4,784–4,904 ft with no reported shows.
54 Twining Drilling Corp. No. 2 NFT	28-4N-1E	2002	9,160	T.D. in tertiary sediments. Converted to water supply well.
55 Twining Drilling Corp. No. 1 NAT	22-4N-1E	2003	12,320	Perforated & fractured 11,936–12,279 ft. Plugged and abandoned.
56 XTO Energy No. 1 Armijo Trust	27-10N-1W	2005	6,080	Coalbed methane exploration well. Plugged and abandoned.
57 XTO Energy No. 15 Westland 1	15-10N-1W	2006	6,697	Coalbed methane exploration well. Plugged and abandoned.

GEOLOGIC ELEMENT	DESCRIPTION	PRIMARY OCCURRENCE IN ALBUQUERQUE BASIN
Source rocks	Organic-rich sedimentary rocks. Generate oil and/or natural gas when buried deeply for long periods of time.	Cretaceous shales
Reservoir rocks	Porous and permeable rocks through which oil and natural gas can move and accumulate.	Cretaceous sandstones
Seals	Impermeable rocks that block the movement of oil and gas.	Cretaceous shales
Traps	The geometric arrangement of a reservoir rock and a seal (or seals) that stops the natural upward movement of oil and gas through a reservoir rock.	Domes or anticlines associated with deep fault blocks.

Geologic elements needed to form an oil or natural gas field.

wells drilled by Shell in its exploratory effort in the basin. As already discovered productive gas reservoirs throughout the U.S. (including New Mexico) gradually become depleted, interest in exploration in "frontier" basins such as Albuquerque will increase along with the need to replace reserves that have been produced elsewhere.

If a future well encounters natural gas and natural gas liquids in a reservoir thought to have commercial viability, additional wells will be drilled to confirm the discovery and to evaluate field distribution and size. If the field as a whole is then considered to be economically viable, development wells will be drilled and production will follow. Given the great depths to potentially productive reservoirs in the deeper parts of the Albuquerque Basin, regulatory well density (or spacing) would likely limit the productive wells to one or two per section (square mile), although this may be doubled to two to four wells per section if the reservoir has low permeability. With the depths and reservoir pressures anticipated, this well density will allow for efficient recovery of gas from the reservoirs.



Typical arrangement of a folded reservoir rock, seal, and source rock that forms a trap.

Gas wells typically flow natural gas and associated liquids (natural gas condensates and light oils) to the surface, so that large pumping units typically associated with oil fields are not needed. Instead, only a small wellhead assembly will be visible, and the gas will be transported to market in underground pipelines. Unlike natural gas, liquid hydrocarbons can be stored temporarily onsite in above-ground storage tanks and trucked to market periodically. If the volume of liquids is sufficient, a separate pipeline system can be used to transport these commodities to market. By modern regulatory mandate, drilling sites are reclaimed and revegetated after drilling operations have ceased, whether the well is successful or not. Drillers are required to post a bond to ensure reclamation before any drilling can begin.

Suggested Reading

Oil and Gas Exploration in the Albuquerque Basin, B. A. Black, New Mexico Geological Society Guidebook 33, 1982.

Recent Oil and Gas Exploration in the Albuquerque Basin, B. A. Black, New Mexico Geological Society Guidebook 50, 1999.

Geology of the Albuquerque Basin, New Mexico, V. C. Kelley, Memoir 33, New Mexico Bureau of Mines and Mineral Resources, 1977.